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# THESIS


**AN ANALYSIS OF AVIATION DEPOT SUPPLY SUPPORT**

by

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December 2000

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The Office of the Secretary of Defense (OSD) issued a Program Budget Decision (PBD) requesting a study of supply material availability (SMA) and related issues for Naval Aviation Depots (NADEPs).

PBD-405 shows a disparity between percentage levels of supply support for the NADEPs and the current overall fill rates published by the Navy Inventory Control Point-Philadelphia (NAVICP-P) and the Defense Logistics Agency (DLA). This thesis evaluates the effectiveness of SMA and determines if SMA is a valuable measurement tool for NADEPs, determines if supply support has an impact on production, and determines if NADEPs are receiving poor supply support. This thesis evaluates the Air Force and United Airline Services (UAS) depot support to determine any common trends or ways to improve NADEP support. After conducting procedure and policy reviews, interviews and site visits to NADEP North Island, ALC Hill, UAS San Francisco and Defense Supply Center Richmond (DSCR), this research concludes that SMA, in its current formulation, is not effective as a measurement tool to indicate supply effectiveness in terms of operational readiness. Also, this research has determined that there is a major link between poor material support and production cycle time. The study recommends the government review post production support plans, pursue standardization, review contract specialist and item manager staffing, and identify and analyze readiness measurement tools.


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# AN ANALYSIS OF AVIATION DEPOT SUPPLY SUPPORT

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# LIST OF ACRONYMS

| | |
|---|---|
| ADB | Aircraft Discrepancy Book |
| AFB | Air Force Base |
| AFMC | Air Force Material Command |
| ALC | Air Logistics Center |
| ALT | Administrative Lead Time |
| $A_O$ | Operational Availability |
| ASPA | Aircraft Service Period Adjustment |
| AWP | Awaiting Parts |
| BB | Backordered |
| BCP | Basic Check Period |
| BOA | Basic Order Agreement |
| BRAC | Base Realignment and Consolidation |
| CNO | Chief of Naval Operations |
| DLA | Defense Logistics Agency |
| DMAG | Depot Maintenance Activity Group |
| DSCR | Defense Supply Center Richmond |
| DSCP | Defense Supply Center Philadelphia |
| FAA | Federal Aviation Administration |
| FAD | Force Activity Designator |
| FCF | Functional Checkflight |
| FISC | Fleet and Industrial Supply Center |

| | |
|---|---|
| FY | Fiscal Year |
| GAAP | Generally Accepted Accounting Principals |
| IPG | Issue Priority Group |
| ISO | International Standardization Organization |
| JCS | Joint Chief of Staff |
| LECP | Logistics Engineering Change Proposal |
| MILSPEC | Military Specification |
| MMTL | Material Management Team Lead |
| MPV | MidPeriod Visit |
| MSRT | Mean Supply Response Time |
| MTBF | Mean Time Between Failure |
| MTTR | Mean Time to Repair |
| NAVAIR | Naval Air Systems Command |
| NAVICP-P | Navy Inventory Control Point-Philadelphia |
| NADEP | Naval Aviation Depot |
| NAMP | Naval Aviation Maintenance Program |
| NMCS | Non-Mission Capable Supply |
| OSHA | Occupational Safety and Hazard Administration |
| OSD | Office of the Secretary of Defense |
| OSP | Operational Service Period |
| PBLC | Performance Based Logistics Contracts |
| PBD | Program Budget Decision |

| | |
|---|---|
| PD | Priority Designator |
| PDM | Planned Depot Maintenance |
| P&E | Planning and Estimating |
| PLT | Procurement Lead Time |
| PPBS | Planning, Programming, and Budgeting System |
| PPSP | Post Production Support Plan |
| PSBA | Product Support Business Area |
| RFI | Ready For Issue |
| ROP | Reorder Point |
| SAIC | Science Applications International Corporation |
| SECDEF | Secretary of Defense |
| SMA | Supply/System Material Availability |
| SMAG | Supply Management Activity Group |
| SOH | Stock On Hand |
| TAT | Turn Around Time |
| TYCOM | Type Commander |
| UAS | United Airline Services |
| UICP | Uniformed Inventory Control Point |
| WCF | Working Capital Fund |
| 2LM | Two Level Maintenance |

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To all we wish peace and happiness!

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# I. INTRODUCTION

## A. PURPOSE

In this study we evaluate the current supply support of aviation depots and address questions concerning Naval Aviation Depot (NADEP) supply support, the effectiveness of SMA (system material availability) as a measurement tool, and the impact of supply support on production as outlined in Program Budget Decision (PBD) 405. A Program Budget Decision is a Secretary of Defense (SECDEF) decision authorizing changes to a submitted budget. [Ref. 4:p. 233] This particular PBD was a result of a request by the Naval Air Systems Command (NAVAIR) to increase the budget for NADEPs due to a civilian pay increase and increased customer orders. This document approves this requested adjustment and requests the Navy to study NADEP supply support. Our research is focused to the needs of the Naval Air Systems Command (NAVAIR) and the Naval Inventory Control Point-Philadelphia (NAVICP-P). Those unfamiliar with NADEP organizations will find clarifying details in chapter three.

PBD-405 shows that the (SMA) fill rates of NADEPS (Cherry Point, Jacksonville, North Island) are much less than fleet averages. These fill rates are generated by NAVICP and reflect NAVICP's and DLA's ability to fill requisitions on the first pass. Specific details on SMA will follow in chapter two. NAVICP maintains these statistics, for they own the aviation components that the NADEP's repair. As item manager and owner of the material, NAVICP-Philadelphia is responsible for forecasting induction requirements and providing that information to the NADEP for scheduling and

resource planning. DLA is an intricate support organization as well. DLA owns and manages the wholesale stock that NADEP North Island uses to repair components and maintain warehouses and distribution centers throughout the continental United States. Material that is required to repair a component is requisitioned from DLA, who is responsible for managing those items and filling customer orders. The tool measuring this filling of customer orders is SMA, and it is defined as the percent of requisitions, which are satisfied/filled on the first pass against system assets. SMA for NADEPs fall well below the 85% NAVICP-P published fill rates for the Navy.

| | All | Cherry Point | Jacksonville | North Island |
|---|---|---|---|---|
| **Oct 98** | 70 | 69 | 73 | 68 |
| **Nov 98** | 68 | 76 | 71 | 51 |
| **Dec 98** | 70 | 74 | 73 | 59 |
| **Jan 99** | 75 | 69 | 82 | 71 |
| **Feb 99** | 69 | 74 | 69 | 63 |
| **Mar 99** | 70 | 65 | 78 | 61 |
| **Apr 99** | 70 | 65 | 70 | 75 |
| **May 99** | 73 | 70 | 72 | 78 |
| **Jun 99** | 73 | 70 | 74 | 75 |
| **Jul 99** | 74 | 70 | 74 | 78 |
| **Aug 99** | 68 | 61 | 71 | 73 |
| **Sep 99** | 69 | 77 | 68 | 60 |

Table 1. FY 99 SMA percentages for NADEPs [From PBD-405].

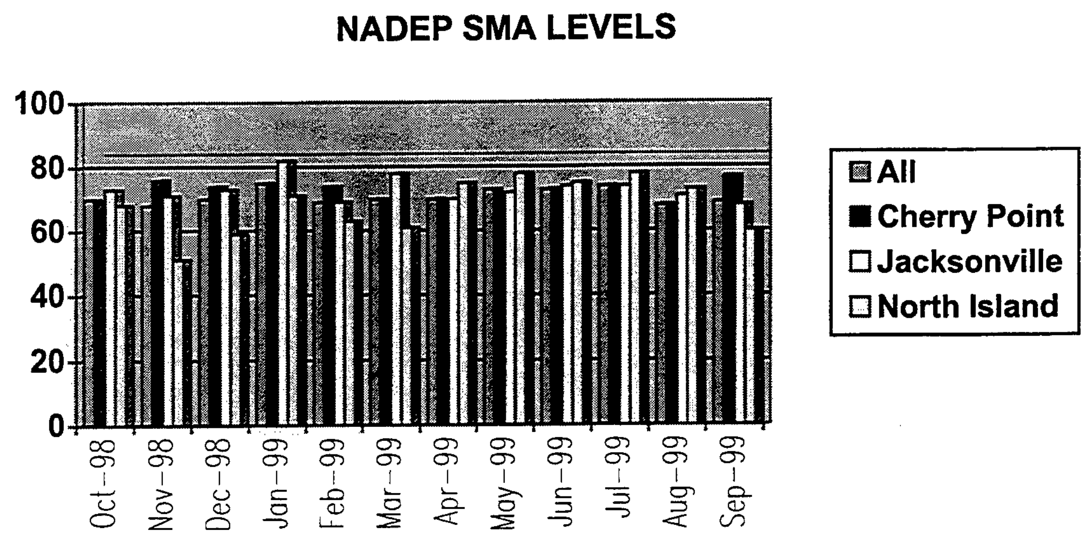


Figure 1. FY 99 SMA graphical comparisons. Note: The line at 85% depicts the Navy published goal for SMA.

Considering the current military environment of diminishing funds and a management focus on best business practices, the Office of the Secretary of Defense (OSD) and higher echelon leadership have targeted selected organizations for potential improvements in inefficiency and or ineffectiveness. They are using a core competency philosophy to determine what the organization does well and what might be outsourced. This effort identified the disparity in depot SMA compared to fleet SMA. This caused OSD to question both the effectiveness of (SMA) in measuring supply support for NADEP production and whether the current supply system contributes to long turn around times in NADEP production. Additionally, OSD would like recommendations for improving both of these areas of concern.

There are many underlying variables contributing to supply support effectiveness, including forecasting, scheduling, and aging aircraft. Forecasting and scheduling

effectiveness and efficiency directly affect the certainty of requirements. Any error in these areas can directly cause a rippling affect promulgating a significant time lag in obtaining resources. An aged aircraft system can severely impact support effectiveness through compounded uncertainty and lack of suppliers. This causes excessive delays in turn around time. In this thesis, we observed the variables, studied depot supply support procedures, assessed the effectiveness of SMA as a measurement tool, compared Air Force and United Airlines Services (UAS) and recommended courses of action.

## B. RESEARCH QUESTIONS

Our research addresses the following research questions:

- What are the components of SMA?
- Is SMA a good indicator of NADEP supply support?
- Is NADEPs' production impacted by the "poor supply support", as stated in PBD-405?
- What other tools might measure NADEP supply support?

## C. SCOPE, LIMITATIONS AND ASSUMPTIONS

Each Depot Organization is extremely dynamic and complex; for example, NADEP North Island manages Planned Depot Maintenance (PDM) for the F-18, E-2, S-3, C-2, H-60 and their respective components as well as those of other aviation platforms. A comprehensive study of the range of production and supply support analysis is beyond the scope of this thesis. Our thesis will focus on a sample PDM platform for each depot system (Navy, Air Force, and UAS) that best employs all the facets of the current supply system in each organization.

The Navy Aviation Depot system consists of three major facilities; NADEP Jacksonville, FL; NADEP Cherry Point, NC; and NADEP North Island, CA. In this thesis, we will analyze SMA at NADEP North Island, because of its unique and interlocking partnership with the Fleet and Industrial Supply Center (FISC) San Diego.

We selected the F/A-18 platform as our PDM sample for NADEPs because it engaged the most supply support functions, allowing a whole supply system observation. Incidental to studying the backorders for the E-2, C-2 and S-3, we discovered these platforms did not use all facets of the supply system and were experiencing excessive turn around times (TAT); 67, 150, and 210 days respectively. Our studies indicated the primary cause for long TATs was extensive delays in part arrival time. This is a direct result of aging aircraft systems.

We found that each of these platforms has been out of production for an average of 15 years and its service life has been extended beyond initial expectations. As a result, a significant number of aircraft component suppliers are no longer producing components for these aging systems. The lengthy time waiting for parts is primarily due to long lead-time for procurement contracts. We observed weaknesses in the Post Production Support Plan (PPSP) and highly recommend an in-depth review of PPSP for all aging systems, as well as scrutiny of PPSP in current systems. Although a significant and common cause of aging aircraft issues are supply delays in all of the depot systems we observed, they are issues of mismatching input resources and output requirements and a diminishing Defense Industrial Base. These issues require immediate attention for the health of Naval Aviation and higher level of analysis is beyond our scope.

The Air Force Aviation Depot System consists of three Aircraft Logistics Centers (ALC); Hill ALC, Ogden, UT; Warner Robins, ALC, Warner Robins, GA; Tinker ALC, Oklahoma City, OK. Our thesis analyzes Hill ALC, as the Air Force sample because of its experience conducting depot maintenance on the F-18 program during the period July 1993 to December 1995 and its experience conducting PDM on both Navy and Air Force C-130s.

After examining each production line at ALC Hill (A-10, C-130, F-16), we selected the C-130 as the PDM platform to compare to the NADEP system. The other PDM system (A-10) did not engage enough supply system functions because it is experiencing the same aging aircraft implications as the E-2, C-2, and S-3 platforms from NADEP, North Island.

Our commercial example, United Airlines Services (UAS), has three maintenance facilities: San Francisco, Oakland and Indianapolis. We have selected UAS, San Francisco, CA because of its throughput and proximity. It serves B-700, A- 319, and A-320 series aircraft, plus five engine types. While, UAS San Francisco is no longer an in-depth maintenance facility, C-checks and major engine work are performed in the San Francisco plant. The data provided was very useful as a reference point for the commercial industry. UAS also experienced aging aircraft difficulties, and resolved them initially by purchasing used whole aircraft for parts. Subsequently, they found more value in replacing the aged systems with newer systems.

One of the constraints aside from those mentioned is the military funding process that fixes labor and overhead rates two years in advance of the work performed. This

process is called the Planning, Programming and Budgeting System (PPBS) and can only be changed by law. As a result, change recommendations concerning this system are beyond the scope of this research. The funding system can significantly impact the ability to schedule jobs and order parts, which creates uncertainty and increases supply lead times. The two military aviation depots are both Working Capital Funds (WCF) relying on reimbursement through customer appropriated operations and maintenance funds. Government budgeting uses expected expenditures several years ahead of schedule, which introduces a funding-timing problem that significantly affects supply support. The projected requirements at the time of the budget submission can significantly change by the time of budget execution. Labor rates and fixed overhead rates can increase in this time frame, due to pay raises as in PBD-405 and increased costs; however the military depots are required to use the fixed rates. This creates a shortage of available funding for labor and parts, causing a mismatch of needs and resources. Unanticipated workload can also cause a mismatch of needs and resources.

For example, in two years a trend in component failure may surface that requires immediate readiness attention to avoid grounding a platform and crippling readiness. This cannot be projected two years earlier during the budget process. Therefore, there is a lag in resources that affects the military's ability to acquire supply support. Under the current budget system, if an organization suddenly has a heavy unanticipated requirement for a certain part, there is risk that 1) limited funding exists to pay for the part and either funds are taken from another item or 2) managers suffer delays in trying to procure a contract. This risk is minimized in a budget that can expand and contract more easily, which requires reforming the Planning, Programming, and Budgeting System (PPBS).

## D. ORGANIZATION/METHODOLOGY

In our research we began by examining the definition of SMA and the variables that could lead to the noted fill rate disparity. We then evaluated the depot support systems using a sample PDM system for the Navy, Air Force, and UAS. By identifying and comparing relevant variables of supply support delays across the respective supply systems, we made recommendations for improving NADEP supply support.

Chapter I provides the background, illustrating the level of concern. It outlines the structure and scope of the thesis. In Chapter II, we analyze whether or not SMA is an appropriate tool for measuring supply support effectiveness for depot production. This Chapter explores the SMA formula and defines its respective variables. Additionally, it summarizes variables contributing to AWP time that are excluded from the formula. Chapter III provides background on NADEP operations and assimilates data on prevalent readiness degrader systems of the sample F-18 PDM platform. We break these degrader systems down into respective parts requirements, their supply source and the variables delaying parts receipt. We then identify the primary causes for supply delays affecting production. Chapter IV and V follow the same structure for the Air Force and commercial aviation depot systems, respectfully. In Chapter VI, we compare background procedures on all three systems and match them with problem variables to provide realistic recommendations that have proven successful. We also delineate conclusions on the overall assessment outlining areas of further research.

We visited the three sites discussed to collect background information and data, and discuss supply support issues with resident supply, production and planning

personnel. Additionally, we visited Defense Supply Center Richmond (DSCR) to observe procedures and conduct interviews with supply personnel.

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# II. SMA AS A MEASUREMENT TOOL

## A. DEFINITION

SMA is defined as the percent of requisitions satisfied/filled on the first pass against system assets. It is prepared monthly by a computerized Uniformed Inventory Control Point (UICP) program. The current Navy goal for SMA is 85%. [Ref. 1:p. 44] The formula for SMA is as follows:

$$\text{SMA}(\%) = 100 \times \{1 - \frac{(\text{Backorders Established} + \text{PBLCs Established})}{\text{Demand}}\}$$

Performance Based Logistics Contracts (PBLCs), formerly called Direct Vendor Delivery (DVD), are items requisitioned by end users that are directly delivered from the vendor surpassing the navy system. These are long term contracts that are already in place and employ equivalent logistics time frames as the Navy Supply System. NAVICP establishes a (PBLC) contract with a vendor to manufacture certain National Stock Numbers (NSNs). The vendor uses NAVICP previous demand history to determine the quantity per NSN that should be manufactured per quarter. From this point, NAVICP no longer manages the items. The items are managed by the vendor include warehousing. When an activity places a requisition for a PBLC item, the requisition is sent directly to the vendor via NAVICP's database. The vendor pulls the item from the warehouse and ships the item to the activity.

The Backorders and the PBLCs consist of the items not supplied by the Naval Supply System. For example, a SMA of 85% means that 85% of the requisitions placed

into the system is being filled by the Naval Supply System. This measures the effectiveness of Navy supply in filling requisitions of items normally stocked; it includes all requisitions – both consumables and repairables. It reflects Navy Supply's ability to fill any requisition. This measurement tool only reflects the quantity of requisitions filled. It does not reflect the criticality or priority of the requisitions being filled.

## B. SMA'S EFFECTIVENESS AS A TOOL

When selecting an effectiveness measurement tool, it is critical to consider both who will be using the tool and their definition of effectiveness. SMA measures the Navy Supply System's ability to fill requisitions. The user for this tool is Navy Supply Inventory Managers, and the end calculation reveals whether or not Navy Supply has the inventory to fill all supply requirements on the first pass. This does not necessarily translate to supply effectiveness or readiness. If managers use SMA to measure supply effectiveness or readiness, as in PBD-405, they will draw the wrong conclusions.

To further illustrate this misreading, consider an organization having one hundred requisitions for the month; fifty requisitions are filled for paper, pens etc, thirty-five are filled for maintenance actions, five are backordered and ten are PBLCs. Using the formula, we would calculate SMA to be 85%. This formula lumps all requisitions types together, whether it is pens and papers for note taking or a hydraulic pump preventing an aircraft from flying. Pens and paper will most likely be negligent in affecting overall readiness, where as the hydraulic part will seriously degrade readiness.

If you went to war with the presented scenario, you could administratively create a strategic plan with the excellent fill rates for office supplies (fifty requisitions filled),

but backorders and PBLCs for critical supply parts (five backordered, ten PBLCs) might prevent the Navy from executing its strategic plan. SMA does not discriminate priorities. SMA would equal 85%, indicating that effectiveness is good; yet readiness maybe poor.

Determining the appropriate measurement tool depends on the characteristic being measured. If we are interested in readiness or production, PBLCs should not be subtracted from the total obligations filled. With the current formula for SMA, a large number of direct vendor deliveries or PBCLs would generate a low SMA; yet readiness would be good if you fill the requisitions and the weapon systems continue to operate. Alternatively, if an item manager is deciding if the Navy should keep a certain portion of inventories in house, then SMA becomes a more effective tool.

The question posed in PBD-405, "Is SMA a good indicator of supply support to the NADEP" is asking if the tool used to measure Navy Supply System supply support is effective at measuring total NADEP supply support, not just Navy support. The answer is that it is the wrong tool. Assuming that we are interested in NADEP supply support to ensure NADEP production readiness, SMA only considers Navy supply support. When we observe the NADEP backorders and PBLCs, we note that the SMA can be low because of high backorders or because of high PBLCs. If NADEP relies on PBLCs, this would lower SMA even though parts requisitions are filled directly. Using SMA to measure total supply support would inappropriately indicate that supply support is low.

If we are concerned with the effectiveness of supply for production, we are not necessarily concerned about the source of supply. We would like to examine Supply's ability to fill requisitions from any source on the first pass of critical parts that affect

production. We can directly link the impact of supply on production, recognizing that any backorder can delay production. This is reflected by removing the PBLCs from the formula and creating a new measurement tool SMA':

$$\text{SMA}'(\%) = 100 \text{ x } \frac{\{1 - \text{Backorders Established}\}}{\text{Demand}}$$

This formula succeeds in isolating backorders and eliminating effective supply sources (PBLCs), but it does not account for skewed data because of variable priorities. In other words, a high SMA could result from a high requisition of low priority items that are not necessarily critical to the production process (i.e. indirect materials). Priority is very difficult to incorporate into a measurement tool because priorities can change. For example, a consumable gasket that is normally low priority could cause a production delay; if it is critical, the production manager can raise the priority. In the case of measuring supply support impact on production, priority requisitions are a critical aspect of readiness.

To focus on readiness critical requisitions, it is more useful to look at SMA by Issue Priority Groups (IPGs). The IPG determines the requisition's Priority Designator (PD). The PD (01-15) expresses the relationship between the requisitioner's assigned force activity designator (FAD) and the selected urgency of need, and determines the time frame within which the requisition will be processed. [Ref. 3:pp. 3-16] The FAD is a Roman numeral (I through V) assigned by the Secretary of Defense (SECDEF) and the Joint Chief of Staff (JCS) to indicate the mission essentiality of a unit, organization, installation, project, or program to meet national objectives. [Ref. 3:pp. 3-64]

In particular, IPG 1 and 2 would illustrate the effectiveness of supply support on readiness critical requirements. IPG 1 and 2 consist of the most critical requisitions, those with priority designators 01 through 03 and 04 through 08, respectively. PD 01 through 03 means that a unit or organization is unable to perform its mission. PD 04 through 08 means that a unit or organization's ability to perform its mission is severely impaired.

By using IPG's, changing priorities are already incorporated because decision makers can raise the IPG in circumstances allowed by readiness requirements and appropriate authorization. If we can focus the new SMA formula on these high priority requisitions, we can measure the critical impact of supply to production readiness. We will measure the "show-stopping" supply difficulties. This new formula $SMA_{IPG\ 1\&2}$ will give us a better indication of supply impact on production readiness:

$$SMA_{IPG1\&2}(\%) = 100 \text{ x } \frac{\{1 - Backorders_{IPG1\&2}\}}{Demand_{IPG1\&2}}$$

Another measurement tool that is appropriate and has already been established is Gross Effectiveness. This tool also measures supply support effectiveness in terms of readiness. Gross effectiveness is the percent of total requisitions, for both stocked and non-stocked items, received and satisfied from stock on hand at any given level of inventory. In other words, it is the percent of total requisitions filled on site. Gross effectiveness is mainly used by stock points and supply departments to measure customer service. [Ref.1:p. 44]

Many managers may be tempted to use Operational Availability ($A_0$). The formula for $A_O$ is:

$$A_o = \frac{MTBF}{MTBF + MTTR + MSRT}$$

Where:

MTBF = Mean time between failure

MTTR = Mean time to repair

MSRT = Mean supply response time

This tool is not appropriate to measure supply support in the question posed in PDB-405, "Has NADEP production been impacted by poor supply support?" $A_O$ could provide a preliminary indication of supply impact on production; however, the data would have to be mined further to differentiate Mean Supply Response Time (MSRT) and Mean Time to Repair (MTTR). MSRT would indicate supply's impact on production, while MTTR better reflects manpower, troubleshooting, maintenance, and or availability of support equipment. The most appropriate measurement tools to isolate supply impact on production are $SMA_{IPG1\&2}$ and/or gross effectiveness.

# III. NAVAL AVIATION DEPOTS

## A. BACKGROUND

### 1. Defining a NADEP

In Naval Aviation Maintenance there are three levels of repair: operational level, where technicians remove and replace repairable items; intermediate level, where there is higher technical expertise and more complex repair; and depot level, where the highest level of expertise exists and heaviest "overhaul" maintenance occurs. We will focus on depot level maintenance, which has three general functions: 1) rework of existing aviation end items, including both maintenance and modification, 2) manufacturing items and components, and 3) support services including professional engineering, technology and calibration. The organizational structure is illustrated in Figure 2.

There are three NADEPs conforming to this structure; NADEP Jacksonville, FL; NADEP Cherry Point, NC and NADEP North Island, CA. These NADEPs service different aircraft platforms, but each mirrors the other in most respects. NADEP North Island, the NADEP selected for this thesis, maintains a workload of approximately 30% aircraft repair/overhaul, 24% component repair, 1% engine repair, and 45% support services. The aircraft this facility services include E-2, C-2, F/A-18, S-3 and H-60, with F/A-18s comprising 77% of the aircraft workload. We will focus on the F/A-18 system, because repair and overhaul consume the majority of supplies, and this system comprises the largest workload.

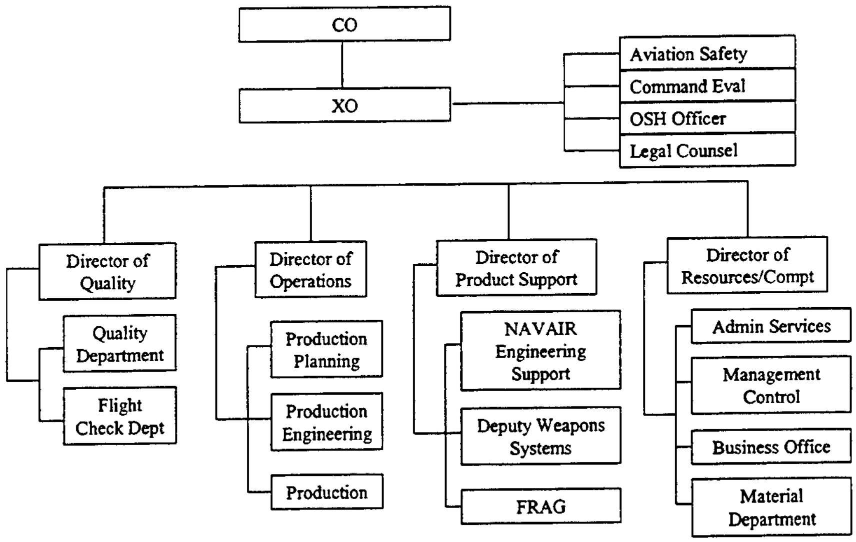


Figure 2. A NADEP Organizational Structure. [From Ref. 5]

We observed the E-2, C-2 and S-3 platforms and found that the majority of supply difficulties were due to aging aircraft. For example, data on C-2 support reveals that a little over 40% of two years worth of requisitions were backorders with excessive lead times due to obsolescent and diminishing manufacturing sources. [Ref. 4:p. 2] These aircraft are in service beyond their original design intent. As a result, there are limited suppliers to provide replacement parts, causing long lead times for supply. This is a serious issue requiring top-level leadership attention.

### 2. Funding

Because a NADEP is a Working Capital Fund (WCF) organization, forecasting workload becomes extremely critical in planning operations. Funds are acquired through job orders place by Operations and Maintenance appropriated activities. There is a cash

corpus that a NADEP may draw from, but the main source of funding comes from these appropriated activities. A customer sends work orders. The NADEP provides the service, pays for the expense and bills the customer. Then, the customer pays the bill replenishing the WCF. The cost of a job is based on rates derived from the full cost of operating a NADEP. This job costing system in each WCF activity must achieve a net operating result of zero for the execution year. This system of funding provides direct input to the workload and resources 2 years in advance; this input can significantly impact forecasting.

Although this system of funding accounts for all costs, it also causes many difficulties in planning. Because funding relies upon Operations and Maintenance appropriations, planning for costs occurs in the PPBS cycle calling for predictions two years ahead of time. Unfortunately, many things can happen between the approval of a budget and its execution. Yesterday's predicted modifications and repairs may not be the same as tomorrow's critical modifications or repairs. Additionally, an operating unit may cancel his job order because of operational commitments. This causes a "death spiral," where the cost of hiring additional personnel for the expected workload is no longer covered by the remaining job orders. This phenomenon causes overhead to be spread over fewer items, which causes the next year's rates to be higher reducing the number of job orders, and driving the future rates even higher.

### 3. Forecasting

Forecasting for aircraft overhaul involves assessing the aircraft operation service period (OSP), which is the time between required depot level maintenance requirements determined by engineering reliability factors. Theoretically, if an aircraft receives

standard depot level maintenance at the end of this service period, the aircraft will be returned very close to its inherent reliability. Ideally, squadrons would receive a replacement aircraft, as they turn an aircraft in to a NADEP at the end of its OSP. But, this does not always happen because of budgetary constraints.

This phenomenon coupled with the fact that aircraft turned into NADEPs appear to have remaining service life laid to the foundation for the Aircraft Service Period Adjustment (ASPA) program in 1982. This program was built on the idea that not all aircraft degrade in condition at the same rate; therefore, aircraft should be inducted to the depot on the basis of material condition. This allows for longer operational use of assets.

The ASPA program is currently used to determine NADEP inductions. This program involves sending a planning and estimator (P&E) team to a squadron to inspect an aircraft at its OSP. The inspector team assesses the aircraft's material condition and either recommends induction into the NADEP or defers it for a year. The P&E team returns the following year and continues the process until the aircraft is recommended for induction. In many cases, aircraft are deferred for an additional ten years. [Ref. 2: p. 6]

Because this maintenance is deferred by subjective means and operational hours are extended well beyond engineering failure determinations, the level of uncertainty significantly increases. This uncertainty complicates NADEP's planning for unanticipated maintenance discrepancies, which results in incorrect labor and material cost and longer turn around times. Uncertainty concerning discrepancies eliminates predictability in expected parts required, labor required and scheduling required. As a result, managers cannot minimize supply lead times prior to induction.

Due to unpredictability and inability to meet budget targets, the Chief of Naval Operations (CNO) directed NAVAIR to eliminate the ASPA program and start a program with established fixed period end dates for all platform overhauls. In 1998, NAVAIR started the Integrated Maintenance Concept (IMC). IMC is a Reliability Centered Maintenance (RCM) based analysis and packaging of O/I/D level preventive maintenance tasks in a platforms Maintenance Plan. This ensures that the tasks are performed at the right location and interval, by the appropriate level of maintenance, providing the highest degrees of availability and readiness at the lowest overall Life Cycle Cost (LCC). Although NAVAIR is requiring all platforms to implement IMC, ASPAs are still being performed in the fleet. Platforms are phasing in IMC at different intervals at different sites. When fully implemented, IMC should eliminate the unpredictability and assist in budgeting for scheduled aircraft maintenance.

#### 4. Induction Planning

Induction planning occurs semi-annually with both NAVICP-Philadelphia for components and NAVAIR for aircraft. During these conferences, demand is matched with capacity and capability to ensure that customers' needs are met and resources are used efficiently. NADEP planners and estimators examine the proposed workload requirements to determine if NADEPs have the capacity and resources to meet NAVICP's or NAVAIR's requirements. Actual inductions are then negotiated to balance repair requirements, plant capacity, resource availability and utilization. The NADEPs take this schedule and develop weekly induction schedules.

### 5. The Overhaul Process

Once an F/A-18 arrives for overhaul, it completes the following phases; induction, disassembly/evaluation, repair/modification, assembly, systems check, and paint. Induction identifies system discrepancies needing repair and modifications requiring implementation, by reviewing logbooks, the Aircraft Discrepancy Book (ADB) and pilot debriefs. The aircraft is then assessed physically. After conducting a material condition inspection to determine corrosion and paint requirements, NADEP engineers disassemble the aircraft for further examination and evaluation. This inspection follows a standard specification, reflecting a checklist of components to inspect based on failure data; engineers compare and evaluate aircraft components against this list of typical repairs required in overhaul. Discrepancies above and beyond the standard specification are also evaluated.

Structural repairs and modifications take place during the repair and modification phase. Parts are removed and replaced; removed, repaired and then replaced; or removed, cannibalized and replaced. The majority of the supply decisions made in this phase directly impact the TAT. Once repairs are completed, the aircraft is ready for the assembly phase. All parts are received and installed during this phase, and systems checks are conducted. The systems test phase continues this testing. Once the checks are complete, the aircraft is forwarded to the test flight line for more systems checks and a test flight. Upon completion, the aircraft undergoes the paint phase, receiving major touch up and zonal painting. The ADB and logbooks are then reviewed and annotated for transfer back to the fleet.

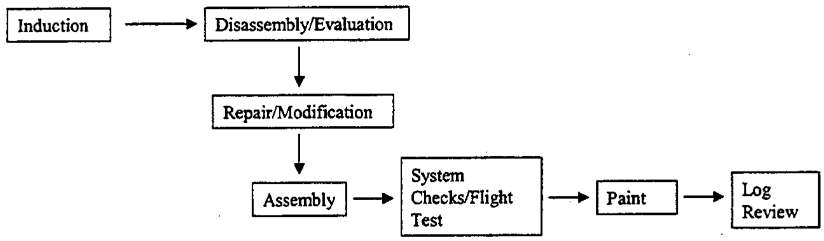


Figure 3. NADEP Aircraft Overhaul Process.

### 6. The Supply Process

NADEP North Island's supply system offers seven options to acquire needed parts. Although some parts are ordered and prepositioned prior to induction, based on specification standards, most requisitions are conducted as early as possible after induction. If a discrepancy requires a part, a requisition is placed in the system. The part can be acquired through:

- Naval Industrial Fund (NIF) Inventory
- Fleet and Industrial Supply Center (FISC) Focus Store
- NAVICP-P
- DLA
- Credit Card Purchase
- NADEP Manufacturing
- Contracting

All NADEPs maintain a NIF inventory; however, NADEP North Island has significantly reduced its NIF inventory to raw material. To make the organization more efficient, NADEP North Island initiated a partnership with FISC San Diego. This unique relationship served as the foundation for a focus store. FISC funding establishes an inventory of parts for this focus store, based on NADEP internal demand information. This is a highly trusting relationship because FISC funds the parts upfront and charges the NADEP when the part is retrieved from the inventory. Both the NIF inventory and the focus store are located on site.

If a part is not in stock in either the NIF or focus store, the requirement is forwarded to NAVICP-P or DLA. If these organizations do not have the inventory, the part is placed in a backorder status and a contract is initiated to procure the part. The contracting process can take anywhere from one to eighteen months. If the backorder status reveals a long lead-time, the part can possibly be manufactured in house, if the specifications are obtainable.

If the part is in the Naval Supply System inventory, which includes the NIF, Focus Store, NAVICP-P or DLA, the Naval Supply System will fill the requisition. If it is not available in the Naval Supply System inventory (i.e. parts do not exist in the system), the part can be manufactured by the NADEP, procured with a credit card or procured by establishing a contract, as seen in Figure 4.

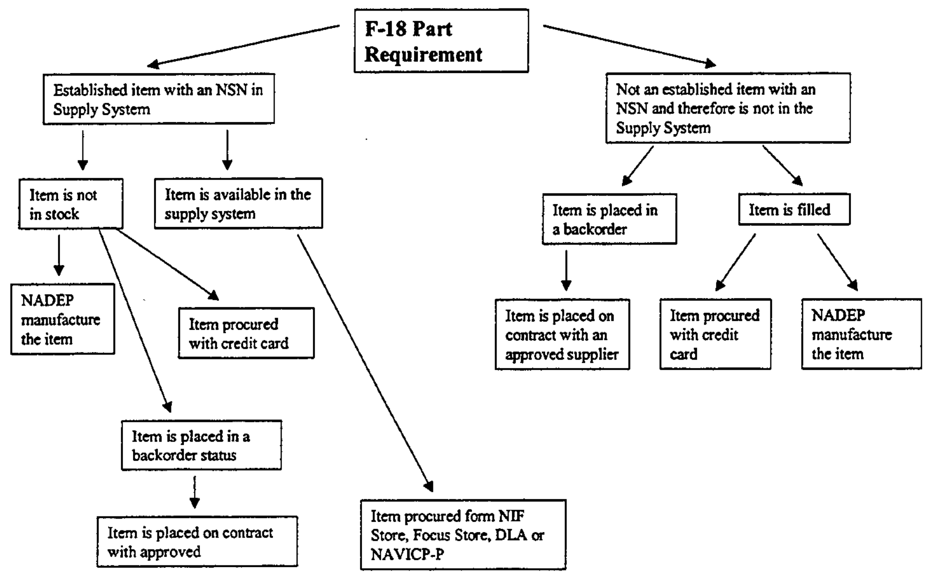


Figure 4. NADEP North Island Requisition Flow.

For fiscal year (FY) 1999, NADEP North Island acquired 1% of their requisitions by manufacturing items in house, 7% through credit card and contracting, 41% from NAVICP and DLA, 38% from the focus store, and 13% are due in from NAVICP and DLA. These results illustrate the FISC partnership through focus stores benefits NADEP, and they show that NAVICP and DLA are the key providers for aviation components.

## B. DATA COLLECTION FOR READINESS DEGRADERS

To assess supply's impact on production, we collected the top 10 F/A-18 readiness degraders (Table 2, page 30). These readiness degraders are components /repair parts that have been backordered long enough to delay overhauls, and the parts shortages plague multiple aircraft inductions. Readiness degraders are used by NAVAIR, Type Commanders (TYCOMs) and NADEPs as management tools to make resource allocation decisions. These are the driving factors in turn around time and production delays.

After identifying the top 10 degraders for the F/A-18, we researched the respective supply status in the fleet. All of these degrader systems are managed by NAVICP. Although NADEP requirements are included in the fleet totals, the causes for supply delays are identical to those in the fleet.

Out of the ten degraders, six are Non-Mission Capable Supply (NMCS). This means that six degraders are components that are critical for the aircraft to fly. Additionally, seven of the components have 0-3 units Ready for Issue (RFI) stock on hand. This means there is no inventory of these components in the fleet; if a weapon system needs the part, the weapon system will no longer be operable. Four of these 0-3 stock on hand components (Hook Assembly, Cylinder and Piston, Main Shock Absorber, Axial Pump) need over 1500 NMCS backordered piece parts to fulfill demand directly for the operating fleet. Additionally, these components have over 4000 backorders of piece parts to fill IPG 1&2 requisitions. In the case of the Hook Assembly, there are over 88,000 backordered piece parts.

We further researched these four backordered components and found average backorder periods to be one year (Hook Assembly), two years (Cylinder and Piston), one year (Main Shock Absorber) and 1.5 years (Axial Pump). Discovering these excessive waiting times, (well beyond the average overhaul turn around time) for supply parts with no inventory on hand, led us to investigate the underlying causes for such a crippling support posture. We found each of these components experienced a drastic increase in demand, followed by the supply system's inability to meet the demand.

### 1. Hook Assembly

The Hook Assembly is provided by Boeing, who is part of a Basic Order Agreement (BOA) with the government. This is a written instrument of understanding, negotiated between an agency, contracting activity, or contracting office and a contractor, that contains (1) terms and clauses applying to future contracts (orders) between the parties during its term, (2) a description, as specific as practicable, of supplies or services to be provided, and (3) methods for pricing, issuing, and delivering future orders under the basic ordering agreement. A BOA is not a contract but may be used to expedite contracting for uncertain requirements for supplies or services when specific items, quantities, and prices are not known when the agreement is executed, but the government expects to purchase a substantial number of the supplies or services covered by the agreement.

Boeing has not been able to meet established schedules and is experiencing long lead times of three years. When an aircraft is broken down for overhaul, NADEP has been experiencing an increasing and excessive scrap rate. In particular, the shank for the Hook Assembly has been difficult to obtain. A Logistics Engineering Change Proposal (LECP) is in progress to modify some of the specifications for this shank and the Dayton and Brown company is testing the hook assembly for service life extension. However, these prospective solutions will not reduce the long lead-time required to receive parts off the production line.

### 2. Cylinder and Piston

The Cylinder and Piston component involves a long-term contract with Castle Precision that began in 1995. This company defaulted because they could never deliver the item. SHL, an Israeli Company, provided a few of the cylinder and piston components, but not the quantity that the schedule required. The fleet began experiencing maintenance problems as well. Two companies All Tool and NASA Tool, won contracts in February 2000 to manufacture these items. The finished products should be delivered to the fleet in the summer of 2001. Normally, the lead-time for such a contract is 2 years; these companies are cutting this by a few months.

### 3. Main Shock Absorber

The Main Shock Absorber experienced an unanticipated 500% spike in demand due to corrosion problems. This was caused by quality and delinquent delivery problems under a sole source contract with an Israeli Company. This five-year contract was initiated in 1995. In response to such an overwhelming demand, a number of CONUS American companies are being contracted to provide multiple avenues to meet the demand. Currently, a New York company, NASA Tooling has passed first article test; All Tool and Blair Industry are going through engineering qualification. By pursuing multiple long-term contracts, NAVICP hopes to prevent similar sole source contracting problems in the future. Once NAVICP's engineering team approves first article testing, the administrative portion of contracting may begin.

### 4. Axial and Pump

The Axial and Pump items are products of a Parker and Hannifin contract that is also a Basic Ordering Agreement, similar to the Boeing agreement. This company is experiencing growing pains after a Virginia plant closed and a plant opened in Kalamazoo, Michigan. The experience of company personnel is limited. Simultaneously, NADEP has experienced problems with the plating process and repeatedly received piece parts that were different with each order. As a result, the company will assemble an overhaul kit with standard bit piece parts required for repair. This kit will have its own part number and will be available in June 2001.

**Key:**

| | |
|---|---|
| NAVICP BB | Actual number of backorders for the entire component. The number in ( ) indicated the number of IPG I backorders for the component |
| SOH | Stock on Hand |
| ROP | Reorder Point |
| NMCS | Non Mission Capable Supply (Requirements of the operational fleet that can not be meet by the supply system) |
| NMCS BB | piece parts backordered |
| IPG I BB | Issue Priority Group I Backorders for piece parts |
| IPG II BB | Issue Priority Group II Backorders for piece parts (Requisitions from Supply Departments to fill inventories up to allowances) |

| # | NSN | NOMENCLATURE | NAVICP BB | ROP | SOH | NMCS (Y/N) | NMCS BB QTY | IPG I BB QTY | IPG II BB QTY |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1560-01-232-8815 | Hook Subassembly/AR | 258 (9) | 406 | 0 | Y | 2040 | 4420 | 84660 |
| 2 | 1560-01-459-1420 | Aileron RH | 16 (12) | 24 | 0 | N | 0 | 0 | 168 |
| 3 | 1620-01-150-6731 | Cylinder and Piston | 51 (34) | 93 | 0 | Y | 1518 | 1716 | 2310 |
| 4 | 1620-01-242-9594 | Shocker Absorber, Main | 76 (24) | 121 | 0 | Y | 2277 | 2574 | 6732 |
| 5 | 1560-01-459-1419 | Aileron | 7 (4) | 29 | 1 | N | 0 | 0 | 91 |
| 6 | 1620-01-220-4432 | Launch Bar Vertical | 17 (1) | 164 | 0 | N | 0 | 0 | 221 |
| 7 | 6610-01-307-0911 | Indicator Axial Piston | 2 (2) | 25 | 14 | N | 0 | 0 | 81 |
| 8 | 4320-01-131-1435 | Pump | 130 (14) | 134 | 3 | Y | 3135 | 3465 | 21120 |
| 9 | 1560-01-383-3284 | Aileron | 39 (30) | 36 | 0 | Y | 94 | 141 | 1034 |
| 10 | 1560-01-383-3294 | Aileron | 23 (15) | 33 | 0 | Y | 90 | 90 | 510 |

Table 2. NADEP North Island F/A-18 Top Readiness Degraders as of 23 Oct 2000.

# IV. AIR FORCE

## A. BACKGROUND

### 1. Levels of Maintenance

The latest AF 21-101 instruction, dated October 1998, describes the Air Force's new level of repair concept. This concept was announced in 1989, concluding an Air Force and RAND Corporation test. The Air Force is phasing in a two level maintenance concept (2LM) versus the previous three levels of maintenance similar to the Navy's operational, intermediate, and depot levels. The Air Force disbanded their intermediate level maintenance facilities for various platforms and disseminated its functions to either the flight line or depot repair shops. Because of a lack of experience and appropriate test equipment in some repair capabilities, the intermediate maintenance level still remains for several aircraft types. Under 2LM, depot repair is tied directly to the flight line and relates directly to unit sortie capabilities. This translates to an operational level of base maintenance that must have enough capability to launch and recover aircraft and sustain the preventive maintenance program.

When a maintenance problem is beyond the first level repair, it is forwarded expeditiously to one of the three Air Logistics Centers (ALC): Tinker ALC, Warner Robbins ALC, and Hill ALC. By eliminating intermediate maintenance, the Air Force is relying on new "Lean Logistics" initiatives and "high velocity" parts movements to compensate for eliminating I-level. In Lean Logistics, the Air Force applies "best business practices" across wholesale and retail functions to reduce inventories and costs

and improve mission capability. These "best business practices" include modern communications, computer controls and transportation initiatives. In this new environment, readiness translates in to improving pipeline processes, moving repairables to depot repair centers and total asset visibility.

### 2. The ALC

An ALC is a major center of Air Force logistics. It reports directly to the Air Force Material Command (AFMC) under the logistics division, which provides a logistics chain of command for the depot.

The Depot is a division of the ALC logistics management directorate. The diagram in Figure 5 further illustrates the depot's command relationship.

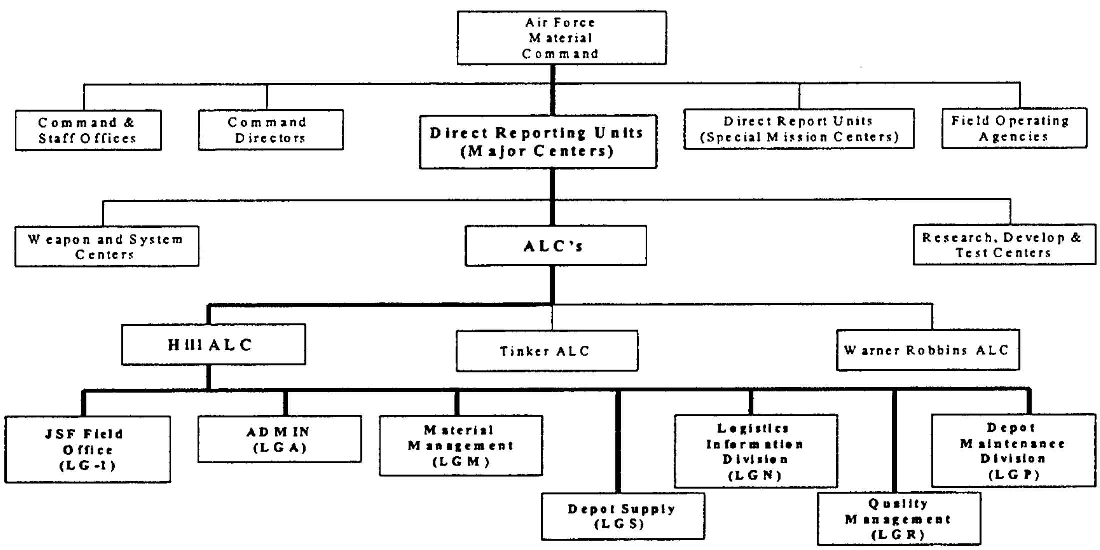


Figure 5. ALC Organizational Structure. [From Ref. 6]

Each ALC provides "industrial support to aircraft repair," and the depot is charged with programmed Depot Level Maintenance (PDM), Unprogrammed Depot

Level Maintenance (UDLM), scheduled modifications and unpredictable requirements to aircraft. A standard Weapon System Support Center (WSSC) structure comprises the depot. Each aircraft system is led by a "fixer" who is responsible for aircraft specific production. The WSSC reports to the fixer, and is a multi-functional, one-stop organization supporting the mechanic. The WSSC synchronizes production management, planning, scheduling and resources. The following diagram illustrates these relationships:

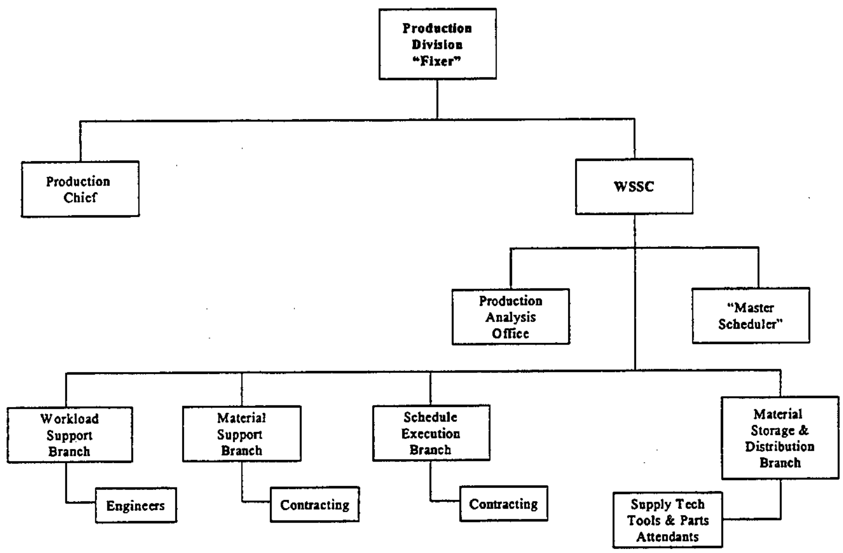


Figure 6. Weapon System Support centers Organizational Structure. [From Ref. 7]

Hill ALC provides depot support to three major aircraft systems; F-16, A-10 and the C-130. We observed the A-10 platform and found that the majority of supply difficulties were due to aging aircraft. This aircraft is in service beyond its original design intent. As a result, limited suppliers provide replacement parts, causing long lead times for supply. We also observed the F-16 process and discovered that this platform does not have a PDM program. It is only under a modification process. As a result, we chose to

focus on the C-130 aircraft. Hill ALC provides depot support on this platform for both the Navy and Air Force.

### 3. Funding

The Air Force depot, like a NADEP, is a Working Capital Fund (WCF) organization. Funds are similarly acquired through the job orders placed by Operations and Maintenance appropriated activities. The Product Support Business Area (PSBA) of the AFMC is responsible for assuring data is provided for forecasting supply and repair requirements. The cost of a job is based on rates derived from the full cost of operating the depot. This job costing system in each WCF activity must achieve a net operating result of zero for the execution year.

This system of funding causes the same difficulties in planning for the Air Force as for the NADEPs. Planning in the PPBS cycle calls for predictions two years in advance, creating a difficult resource situation for the unpredictable modifications and repairs necessary for safety. If more work is required than predicted, or if jobs are scheduled but do not occur, the published cost rates are no longer in line with requirements, causing mismatches in resources.

### 4. Forecasting

Predicting when an aircraft is due for overhaul in the Air Force depends on an established flight hour threshold. This threshold takes into account mission design series and age through a Programmed Depot Maintenance date. The theory is similar to all overhaul systems in that an aircraft receiving standard depot level maintenance at this threshold will be returned very close to its inherent reliability. This scheduled PDM date

is a hard date. It does not have uncertainties like the ASPA program. This reduces the uncertainty in determining workload requirements. If an Air Force aircraft is not inducted within the designated PDM time window, + or – 90 days, the aircraft is grounded. To further minimize uncertainty in workload magnitude and type, the Air Force creates a tail number specific aircraft production schedule, to focus on synchronizing logistics support and direct labor. This allows fixer become familiar with the aircraft in advance and efficiently and effectively plan resources well ahead of the operation start date. The fixer is able to specify a specific work package by mission design and series and by tail number.

### 5. Induction Planning

Induction planning is accomplished by the Material Management Team Lead (MMTL), which includes supply support, inventory storage and distribution, production support, engineering and procurement. This team, along with a supportability team, conducts five types of supportability reviews, to determine the critical path of the process and anticipate and prevent any resource road blocks. The first review is a two-year joint supportability review. The first review determines whether the work is supportable and whether it is approved or not. Once the supportability statement is issued, item managers ensure contracts are in place or renewed so that required supplies are available.

Subsequently, annual supportability reviews are conducted with the master scheduler, planner, fixer, budget analyst, DLA and the engineers. This supportability team ensures all resources are in place; and they determine if stock levels are valid, or should be increased or decreased. Similar quarterly and monthly supportability reviews are conducted. The fifth supportability review is a rolling 10-day "forward look"

conducted by the tail team (the production team that actually performs the work). During these reviews, required parts are reserved in tail number bins to be delivered by a material handler to the forward service area on a just in time basis.

Once a tail number-specific aircraft production schedule is developed, aircraft management will man-load to the schedule on multiple shifts, within existing constraints. This reduces the aircraft in work at one time to increase the flow velocity through the depot. Direct laborers are assigned and prepare the forward support area where the aircraft is repaired and where all other resources will be pulled. This allows the direct labor to focus on their aircraft repair tasks without being concerned with logistics.

To further synchronize scheduling, back shops integrate the aircraft schedule requirements into their scheduling activities. A synchronization team then deconflicts multiple priorities in the back shops across different customers. These are all efforts to minimize the number of flow days.

#### 6. The Overhaul Process

The overhaul process for a C-130 at Hill ALC is very similar to the NADEP's process. However, because a tail number is assigned, the tail team has the added benefit of reviewing the aircraft's specific records prior to induction through a pre-induction conference. The aircraft then goes through a pre-dock inspection and evaluation. The aircraft then goes through a disassembly phase, followed by the indock activities, repair and modification. Unexpected discrepancies are incorporated into the master schedule or deferred back to the operational squadron, depending on resource availability and flight

safety. Added work is supplemented to the non-critical path. Unpredictable requirements are expected to occur less than 20% of the time.

Once repairs are completed, the aircraft is ready for assembly. This phase ensures all parts are received and installed and systems checks are conducted. The post-dock activities include the test flight and painting. The aircraft records are then reviewed and annotated for transfer back to the force. It is important to note that most of the supply decisions are made prior to induction, through the many supportability reviews.

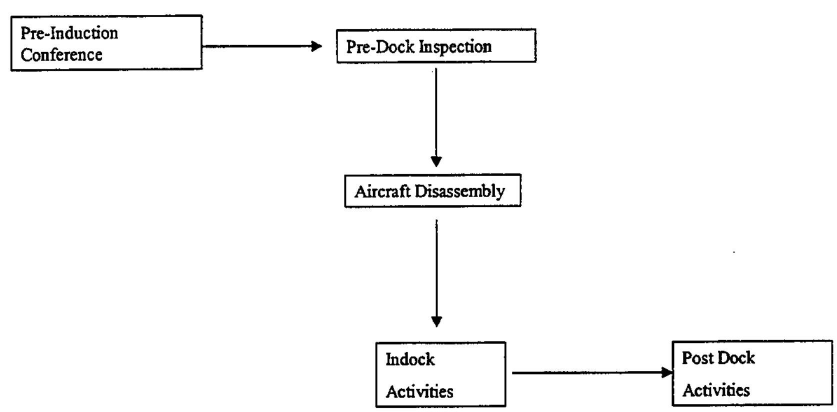


Figure 7. Hill ALC Depot Aircraft Overhaul Process.

### 7. The Supply Process

Hill ALC's supply system offers five options to acquire needed parts. The Air Force stages most common items near the depot for PDMs. If a discrepancy requires a part, a requisition is placed in the system. The part can be acquired through:

- Air Force Inventory (Warner Robbins AFB, Tinker AFB or Hill AFB)
- DLA
- Credit Card Purchase
- Depot Manufacturing
- Contracting

The Air Force inventory includes two types of funding: Supply Management Activity Group (SMAG) and Depot Maintenance Activity Group (DMAG). SMAG is the resource used to fill Air Force spare parts needs in war and peace, and maintains inventory management of approximately 2.2 million items, both consumable and repairable. DMAG overhauls and repairs systems and spare parts directly for the force as well as for SMAG. (SMAG functions similar to NAVICP)

If a part is not in stock in the Air Force inventory, the requirement is forwarded to DLA. If DLA does not have it in inventory, the part is placed on backorder and a contract is initiated to procure the part. If the backorder involves a long lead-time, the part can possibly be manufactured in house, if the specifications are available.

If the part is in the Air Force Supply System inventory, the SMAG, DMAG or DLA, the requirement will be filled by the activity possessing the part. If it is not available in the Air Force inventory (i.e. parts do not exist in the system), the part can be manufactured by the depot, procured with a credit card or procured by establishing a contract, as illustrated in Figure 8.

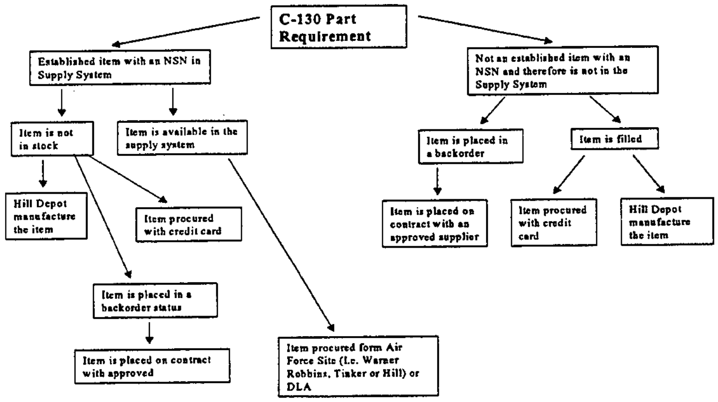


Figure 8. Hill ALC Depot Requisition Flow

For fiscal year (FY) 1999, Hill ALC acquired 3% of their requisitions by manufacturing items in house, 12% through credit card and contracting, 43% from DLA and 32% from SMAG/DMAG. These results illustrate that the Air Forces' focus on high velocity expediting of parts has increased reliability of both in-house inventory and Hill's contracting personnel.

## B. DATA COLLECTION FOR READINESS DEGRADERS

While collecting data at Hill ALC, we discussed the supply posture and production scheduling for the C-130 with both the master scheduler and the material manager. The master scheduler revealed that the flow time for Navy C-130s (132 days) was longer than the flow time for Air Force C-130s (112 days). At least two factors are responsible. The first involves the ASPA program, the scheduling system for C-130's, and its subsequent unpredictability. In an effort to minimize unpredictability, Hill ALC received assigned tail numbers from NAVAIR for the first time. However, Hill ALC was

waiting for ASPA results on the first tail number assigned aircraft. If the aircraft passed ASPA inspection, Hill ALC would loose 16,000 hours. The second factor was the additional work required in the Navy specification. For example, Navy aircraft require wheel well blasting because they are more corroded. This is a specification that the Air Force does not require.

The material manager indicated that Hill ALC has a fairly successful supply posture. They rarely had supply difficulties because they could initiate their own contracts with commercial companies. C-130s also have many commercial applications. However, most of the difficulties they experienced related to backorders through DLA. A specific example was a backordered reparable required by Hill ALC that was available through a local vendor. The DLA spot buy program that is supposed to acquire the assets within 24 hours took four weeks, the Hill ALC material activity took a few days to acquire the part.

To further assess supply impact on production, we collected the top C-130 readiness degraders (Table 3). These readiness degraders are components where backorders over a period of time have delayed the overhaul process in multiple aircraft inductions. These are the driving factors in turn around time and production delays.

After identifying the top degraders for the C-130, we researched the respective supply status for each item. These degraders are managed by DSCR or DSCP. Although ALC Hill's requirements are included in the fleet totals, the causes for supply delays are identical to those in the fleet.

Out of the eighteen degraders, fifteen are Non-Mission Capable Supply (NMCS). This means that fifteen degraders are components that are critical for the aircraft to fly. Additionally, none of the components have Ready for Issue (RFI) stock on hand. This means there is no inventory of these components in the fleet; if a weapon system needs the part, the weapon system will no longer be operable

We further researched five of the degraders; Chine Flight Plate, Blind Rivet, Gasket, Anti-Icing Spacer, and Aircraft Cable/Wire rope assembly. Average backorder periods ranged anywhere from 8 months to 1.5 years. Although these waiting times are half the waiting time for F-18 degraders, they are still beyond the average turn around time and impacted production. We further investigated the underlying causes.

**1. Chine Flight Plate**

The Chine Flight Plate is provided by Airborne Technologies Incorporated. It has been backordered since April 1999 and has a long lead time due to procurement difficulties (Administrative Lead Time (ALT) and Procurement Lead Time (PLT) of 420 days). In an effort to minimize escalating backorders and provide a short-term solution, DSCR contracted with Hill ALC in May of 2000 to induct 38 "G" condition assets for repair. "G" condition indicates a component is not in the repair process but is awaiting parts or awaiting induction following the receipt of all required parts. This contract was scheduled for delivery on 19 September 2000. Due to unavailable piece parts, the schedule slipped and delivery has been pushed back to 3 January 2001. DSCR is requesting that Hill ALC provide a partial delivery in December 2000. Their long-term solution involved awarding a contract to Airborne, on 18 October 2000, for 38 assets with

a delivery date of 12 December 2001. With an average quarterly demand of 5, these two contracts should cover backorders and provide sufficient shelf stock.

### 2. Blind Rivet

The Blind Rivet is managed by DSCP. This item has experienced an unanticipated 200% increase in demand over the last 6 months. This is a very high demand, high volume item receiving 500 to 600 requisitions annually. Each requisition involves 100 to 700 rivets. A contract for 215,180 rivets was awarded to "Alfast Fastening System" in Sept 2000, for delivery in Feb 2001. Although this will improve inventory by covering backorders and replenishing shelf stock, the wait from Sept 2000 until Feb 2001 appears excessive for an item as common as a rivet. Additionally, with an average quarterly demand of 41,403, and over 50,000 backorders to be processed, the current order will only meet demand for four quarters before backorders create another problem. There is currently no follow-on contract.

### 3. Gaskets

The Gasket has backorders over eight months old with no contract in place. After speaking with the DSCP item manager, we found that there are contractors to make the item, but that they are waiting for a purchase request to be awarded. The DSCP item managers are overseeing an increased number of line items, increasing the workload on contracting specialists. This reflects the ALC's consolidation and a simultaneous reduction in ALC's labor force due to downsizing. This has caused excessive delays in awarding contracts. Currently, the gasket has a total backorder of 818 gaskets and an average quarterly demand of 875 gaskets.

## 4. Anti-Icing Spacer

The Anti-Icing Spacer is provided by Lockheed Martin, with backorders in excess of 6 months. An outstanding contract was awarded on 25 October 2000, for a quantity of 795 spacers with a delivery date of June 2001. Currently, there are 388 backorders for this item; average quarterly demand is 140 spacers. At the current demand rate, it will only take 3 quarters to deplete the quantity on the existing contract. With ALT of 97 days and PLT of 100 days, action for follow-on contracts has not been established and will cause another stock out.

## 5. Wire rope and Aircraft Cable

The Prison Industry produces the Wire Rope Assembly and Aircraft Cable. They have been unable to meet the delivery schedule. In order to satisfy the immediate requirements, Hill ALC has been routing "G" condition assets to the back shops for repair. Hill ALC has 62 cables and wires that are designated degraders for the C-130. Twenty-six of the sixty-two (42%) have zero stock on hand. For a long term solution, Hill presently has Small Business Innovation Research Engineering (SBIRE) doing first article test for the cables and wires. ALC is requesting that DLA provide a long-term multi vendor contract to alleviate future production delays.

**Key:**

- SOH — Stock on Hand
- ROP — Reorder Point
- NMCS — Non Mission Capable Supply (Requirements of the operational fleet that can not be meet by the supply system)
- NMCS BB — piece parts backordered
- IPG I BB — Issue Priority Group I Backorders for piece parts

- IPG II BB Issue Priority Group II Backorders for piece parts (Requisitions from Supply Departments to fill inventories up to allowances)

| # | NSN | NOMENCLATURE | Standard Unit Cost | ROP | SOH | NMCS (Y/N) | NMCS BB QTY | IPG I BB QTY | IPG II BB QTY |
|---|---|---|---|---|---|---|---|---|---|
| | 1560-01-045-4478 | Chine Flight Plate | $ 3,634.81 | 15 | 0 | Y | 4 | 13 | 2 |
| | 1560-00-326-8581 | Access Cover | $ 9,854.68 | 1 | 0 | Y | 1 | 0 | 0 |
| | 1560-00-716-2904 | Flap Yoke | $ 999.10 | 64 | 0 | Y | 5 | 7 | 0 |
| | 1560-00-691-2945 | Aircraft Skin | $ 2,310.10 | 24 | 0 | Y | 1 | 5 | 4 |
| | 1560-01-301-3230 | Duct Assembly | $ 550.14 | 14 | 0 | Y | 5 | 8 | 1 |
| | 1560-01-326-0829 | Trailing Edge | $ 509.15 | 46 | 0 | Y | 1 | 5 | 4 |
| | 5320-01-143-5079 | Blind Rivet | $ .29 | 156,825 | 0 | Y | 200 | 2703 | 6913 |
| | 5330-00-634-9387 | Gasket | $ 4.90 | 3,417 | 0 | N | 0 | 94 | 145 |
| | 1560-00-673-1555 | Anti-Icing Spacer | $ 7.14 | 590 | 0 | N | 0 | 261 | 3734 |
| 0 | 1560-00-670-2157 | Brush Seal | $ 16.93 | 242 | 0 | Y | 1 | 60 | 0 |

Table 3. ALC Hill AFB C-130 Top Readiness Degraders of 23 Oct 2000.

| # | NSN | NOMENCLATURE | Standard Unit Cost | ROP | SOH | NMCS (Y/N) | NMCS BB QTY | IPG I BB QTY | IPG II BB QTY |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 1560-00-571-1295 | Hook Assembly | $ 170.55 | 145 | 0 | N | 0 | 8 | 20 |
| 12 | 1680-01-320-7417 | Wire Rope Assembly | $ 20.70 | 84 | 0 | Y | 1 | 10 | 17 |
| 13 | 1680-01-320-7428 | Wire Rope Assembly | $ 48.07 | 128 | 0 | Y | 1 | 15 | 1 |
| 14 | 1680-01-321-0007 | Aircraft Cable | $ 7.38 | 630 | 0 | Y | 95 | 128 | 0 |
| 15 | 1680-01-321-0009 | Aircraft Cable | $ 33.42 | 98 | 0 | Y | 4 | 18 | 1 |
| 16 | 1680-01-321-0011 | Aircraft Cable | $ 34.28 | 90 | 0 | Y | 7 | 19 | 5 |
| 17 | 1680-01-321-0685 | Aircraft Cable | $ 48.57 | 70 | 0 | Y | 1 | 3 | 1 |
| 18 | 1680-01-321-0687 | Aircraft Cable | $ 43.17 | 77 | 0 | Y | 2 | 12 | 4 |

Table 3. (cont'd) ALC Hill AFB C-130 Top Readiness Degraders of 23 Oct 2000.

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# V. UNITED AIRLINE SERVICES

## A. BACKGROUND

### 1. The Industry

The commercial airline industry is driven by profit. Large aircraft are such capital intensive investments' that maintenance becomes a "double edged" sword of reliability versus minimizing maintenance down time. Reliability is critical because a cancelled flight can reduce revenues in subsequent flights, and ruin future business reputation, and generates costs for replacement flight vouchers, hotel reservations and related accommodations. To maintain inherent reliability, aircraft must undergo preventive maintenance, as well as modifications and repair. However, every day an aircraft is down for maintenance is a day lost carrying paying customers. United Airline Services (UAS) simultaneously maintains their profitability and reliability by minimizing maintenance cycle times, standardizing aircraft and building alliances.

Minimizing cycle time involves minimizing unpredictable repairs. UAS uses a two level repair system including line maintenance and heavy maintenance. Cycle time is minimized by conducting around the clock maintenance, planning based on data profiles for each aircraft type, and by ensuring parts are immediately available.

The line maintenance level of repair involves removing and replacing items. Line maintenance includes 60 maintenance support stations worldwide. With over $ 400 million in line removable parts, inventory's strategically positioned in support stations located in major airports.

At the higher level of maintenance, UAS processed over 600 airframe overhauls, 600 engine overhauls and $1.5 million in removable aircraft components annually in three heavy maintenance facilities: San Francisco, Oakland, and Indianapolis. Heavy maintenance services cover the following systems:

| **Airframes** | | **Engines** | |
|---|---|---|---|
| B727 | B737 | JT8D | JT9D |
| B747 | B757 | PW2000 | |
| PW4000 | | | |
| B767 | B777 | CFM56 | |
| A319 | A320 | | |

The commercial industry standardizes aircraft types. Two primary manufactures focus on standardization: Boeing and Airbus. Each aircraft, of each aircraft type is configured identically, and most of the systems are similar between types.

Standardization improves spare parts availability, and reduces inventory and maintenance troubleshooting. Additionally, it has led many airlines to build alliances. United Airlines is currently in a "star alliance" with Air France and Delta. These companies have jointly invested in stand-up maintenance service companies that focus on core competencies. This ensures quality maintenance and profitability. Through standardization, these alliances are able to share resources and inventory and avoid union difficulties.

Our study focuses on the heavy maintenance facility located at San Francisco International Airport. Figure 9 depicts its organizational structure.

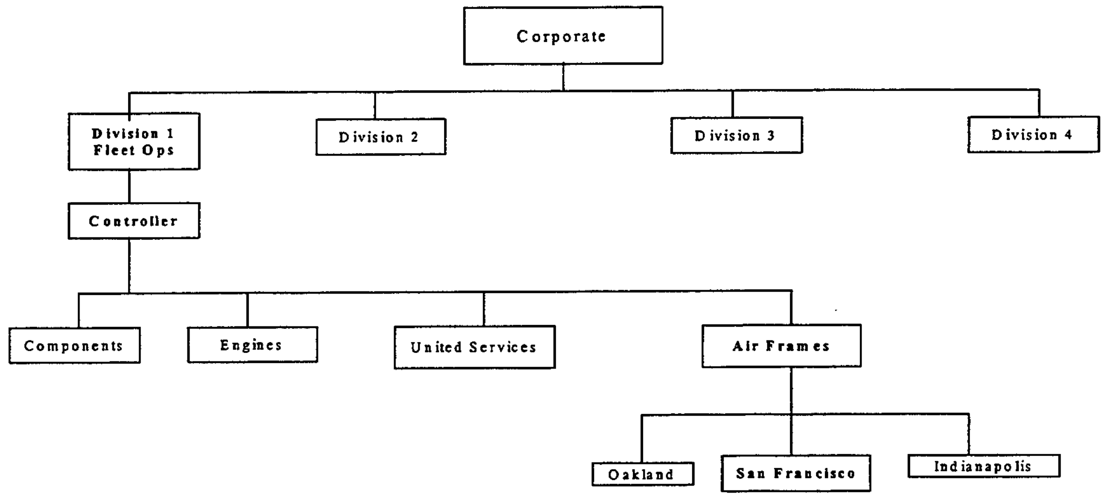


Figure 9. United Airlines Organizational Chart. [From Ref. 7]

### 2. Funding

United Airlines is financially organized by profit and cost centers. Each of these centers develops and submits annual corporate goals using historical data on volume, projected volume, percent mark-up, inflation and exchange rates. Additionally, these centers submit monthly cost and profit forecasts for the current plus 3 subsequent months. Forecasts include probability factors, reliability factors, scrap rates and demand. These are used in an economic order quantity model with policy levels and protection levels. Once these are established, they are placed into the master inventory records and are reviewed periodically for new trends in their internal databases. These forecasts assist in developing an annual budget.

However, centers may exceed these projected amounts. There are many occasions where maintenance shop supervisors order parts and purchasing authorizes funds even

though the costs exceed the budget. Typically, United Airlines Services is over budget every year because of unanticipated repairs. This past year they were $7 million over budget.

### 3. Induction Planning

The base aircraft scheduling division conducts both long range and short range planning. Long range planning consists of a 5 year forecast, called a 5-year dock utilization plan. Induction planning is based on overhaul schedules and other corporate plans. This is translated into a dock utilization plan through the following process:

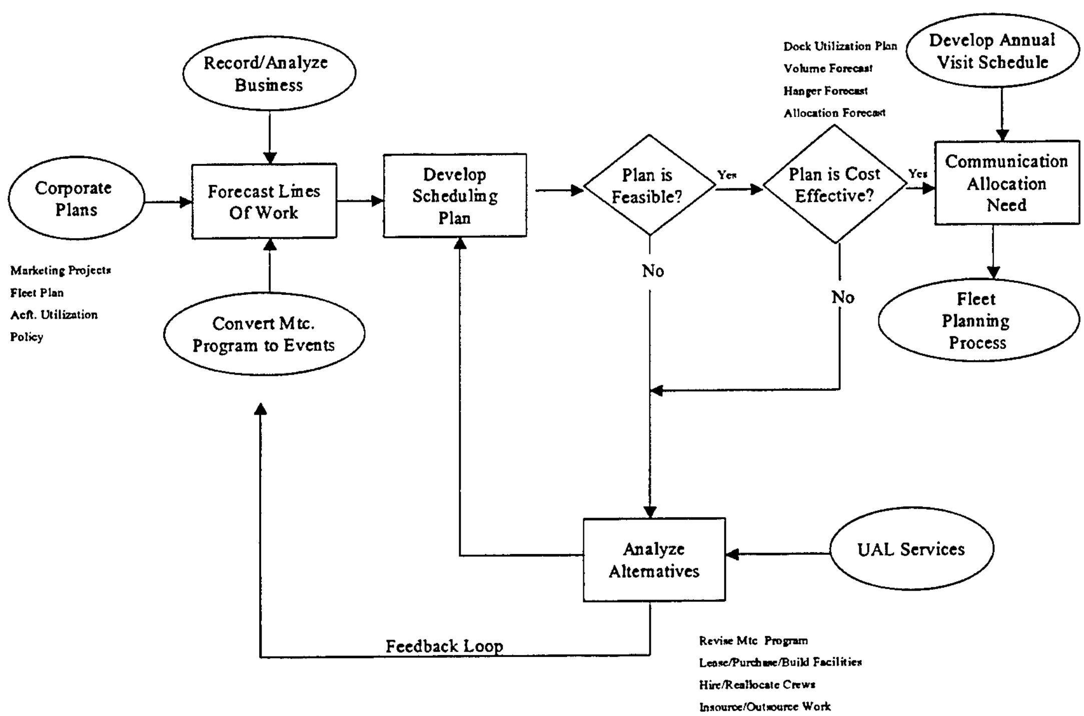


Figure 10. UAL Dock Utilization Plan. [From Ref. 13]

Some of the feasibility considerations incorporated into this plan include:

- Do we have enough physical capacity (hangar/ramp space) to accommodate the planned work?
- Does schedule flexibility constitute acceptable risk?
- Can we get the required allocation?
- Does the schedule/plan meet corporate objectives?
- Does the schedule/plan meet contractual and government regulations?

This long-term dock utilization plan is then transferred into a more flexible short range rolling 18-month plan. This plan takes regular overhaul visits and incorporates special maintenance programs, regulatory requirements, corporate marketing and reliability modifications. This plan is updated continuously with changes in requirements, delays and other contingencies.

Some of the cost considerations include:

- Is there a productivity penalty for alternate locations?
- What are the allocation costs?
- Have we combined comparable visits?
- Are crews and other resources used effectively?
- What is the cost to position the aircraft and/or resources?

To make the planning documents as accurate as possible, communication between maintenance and planning is frequent. Line and heavy maintenance station reviews are conducted at daily meetings, at a six-week review and at a quarterly status and current year review.

### 4. The Overhaul Process

The overhaul process at UAS is a health check system or a series of in depth maintenance sessions that include modification and repair. These checks or visits have

established cycles based on age and ongoing reliability data analysis. The first visit is an A-Check, which is every 400 hours for a B757. The next visit is called a C-Check, which is every 456 days for the 757. During this check, normally lasting anywhere from 10 to 20 days, the aircraft is opened and inspected, high time items are removed and replaced, and service bulletins are often incorporated.

The next level check is a MidPeriod visit (MPV) that is conducted approximately every five years, or at the Base Check Period (BCP). The MPV for a 777 takes approximately 15 days. The next level check is the BCP, which has a 10-year cycle time. This check is conducted over a 60-day period, in which all of the frames are replaced.

Both MPV's and BCP's are heavier maintenance actions, and alternate systems are overhauled. For example, HMV-1 is an MPV that is odd requiring flight controls maintenance, and even HMV's require airframes work. As the aircraft ages, the cycle time expands on these maintenance visits. These cycle times are updated by running a database of average cycle times and required regulations and modifications.

The actual overhaul process is primarily based on the NADEP system. Many of the management tools are very similar to those used by the military. Upon induction, the aircraft is opened and inspected, based on inspection cards similar to Navy and Air Force specifications. Simultaneously, high time items are removed and replaced. Through inspection cards, administrative notes (Federal Aviation Administration (FAA) requirements) and service bulletins, inspectors and mechanics manually write discrepancies.

There are normally 200 job cards for an aircraft. Approximately 250 write-ups normally involve cabin discrepancies. The technicians typically find another fifty discrepancies. These discrepancies are collected and tracked at a center production control, which monitors workloads and prioritizes actions using visual display boards.

Normally all necessary parts are available. There is a general policy against cannibalization; however, there have been occasions when a spare part for a new aircraft that is still in production is not available. In these cases, UAS will cannibalize from the assembly line. The overhaul line is the priority for support. Most delays in cycle time are due to planning and skill sets. The difficulties in planning reflect inadequate post production support programs; the skill sets difficulties reflect deficiencies in technical skills.

Once repairs are complete, the aircraft is assembled. After the aircraft is assembled, functional and operational checks are performed to ensure all systems operate correctly. UAS then sends the aircraft to an outsourced company for painting. UAS outsources painting to avoid all the associated Occupational Safety and Hazard Administration (OSHA) requirements. Lastly, documentation is reviewed before the aircraft is placed back in service. Figure 11 shows the overhaul process at UAS.

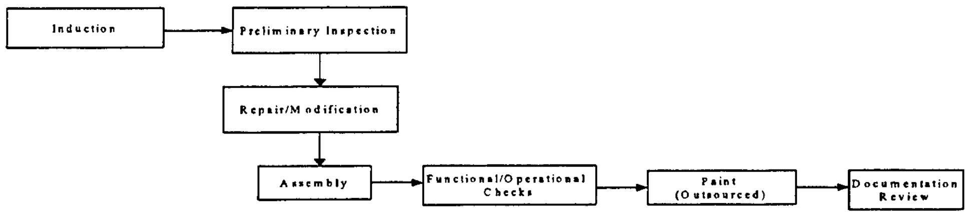


Figure 11. UAS Overhaul Process.

### 5. Supply Process

United Airlines currently conducts supply business with over 200 International Standardization Organization (ISO) certified vendors, but they are reducing this number. Each of the heavy maintenance facilities maintains an inventory of high use items. This inventory is available to all sites and can be easily transferred back and forth using scheduled flights. The forecasting/demand goal is to maintain a 60-day supply on hand at all times.

Every 11 mechanics has a lead mechanic who processes discrepancies and orders parts in the system. If a part is not available in the facility, it is electronically passed to another high maintenance facility. If the part is not available there, it can either be repaired in a back shop or requisitioned from a supplier. The lead mechanic can either go through purchasing for the part, or deal directly with the vendor. Previously, purchases required signatures from lead mechanics, division heads and purchasing. However, the

approval process lasted close to 30 days and purchases were virtually always approved. These approval requirements were eliminated, significantly reducing cycle time.

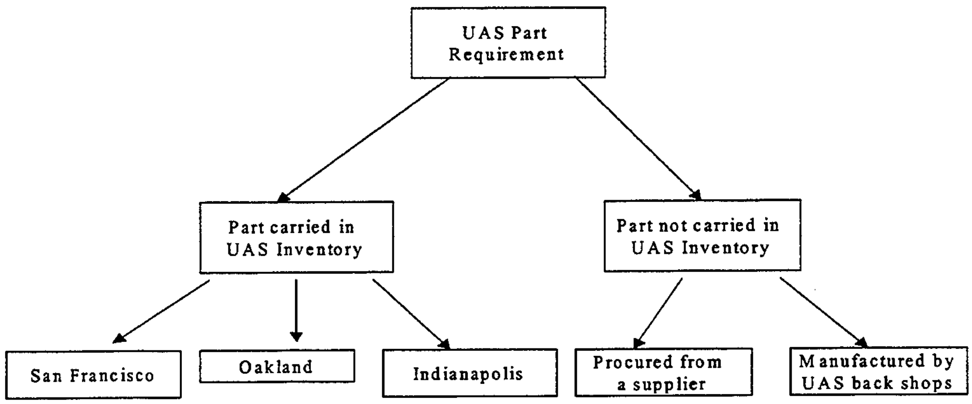


Figure 12. UAS requisition Flow.

Because delays in supply are so costly, forecasting inventory requirements is critical. Inventory forecasting begins with corporate's estimate of flying hours. Using failure rates and cycle times, the number of repairs is estimated. The Material Management Division then takes these scrap rates (rates are updated annually), which are translated into the shop's demand for supply. A safety stock is then added and annual line maintenance demand for supply is added. This establishes the quota:

$$\text{Quota} = DT + SS + MSA$$

$DT = (\text{Daily demand}) \times (\text{Cycle time})$
$SS = \text{safety Stock} = \sqrt{DT}$
$MSA = \text{Max Station Assignment} = \text{Line Demand}$

Once a quota is established, it is published in the master inventory record and used in the economic order quantity model. If a quota is too low, supply will experience expedites; if it is too high, supply will build inventory. The quota can be subsequently adjusted to balance these fluctuations.

## B. DATA COLLECTION/ANALYSIS

UAS has very few backorders, because supply delays translate immediately into lost profit. UAS stocks 95% of their required inventory in their location stock rooms. Using a pre-draw list, they automatically draw parts a month before an expected visit. Only 3% of the required items are not immediately available during this pre-draw period, and they are drawn from other sites or purchased directly from suppliers. Additionally, UAS aggressively manages their suppliers by imposing heavy monetary penalties for delays in meeting requirements. UAS spends approximately $1.5 billion in spare parts and $1 billion in spare engines annually. If a trend in inventory deficiency appears, it is immediately adjusted.

UAS has experienced supply difficulties in two scenarios. The first scenario was related to aging aircraft. This involved the DC-10 aircraft, which is being phased out of their inventory. UAS purchased an additional aircraft and dealt with junk dealers to acquire parts no longer manufactured.

The second scenario involves their newest acquisitions, the B777 and the A320, which are both still in production. They have experienced unanticipated repair requirements in these aircraft that have no parts support. As a result, UAS has cannibalized parts from the aircraft manufacturing assembly lines. The latest example in

this category involved a recent collision between a piece of support equipment and the engine intake of a B777 prior to its first ETOP flight. Post production support planning would have minimized the impact of these premature repair requirements.

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# VI. CONCLUSIONS AND RECOMMENDATIONS

## A. OBJECTIVE

After observing NADEPs, ALCs and UAS, and researching the respective policies, procedures and backorder status, we are able to address the objective questions posed in PBD-405: is SMA a good indicator of NADEP supply support; do NADEP's have poor supply support; and how does it impact production? In general, each depot operated on the same basic foundation; however, each depot system implemented different strategies to minimize these similar difficulties. These different strategies provided proven solutions of similar difficulties in NADEPs and confirmed industry trends in overhaul maintenance.

## B. CONCLUSIONS

- **Using SMA to assess supply effectiveness in terms of readiness is inappropriate.**

  Although measurement tools are merely indicators for further research, they do provide guidance to a more specific research path. We found that using SMA to assess the impact supply effectiveness has on readiness will lead to an inconclusive path, possibly promoting erroneous decision-making and exacerbating the difficulties. This formula does not consider all supply sources, and it considers all requisitions as equal. When assessing readiness, all requisitions are not equal, and we are concerned with critical parts that directly affect readiness (IPG 1 and 2). The SMA formula currently used is appropriate for assessing Navy inventory stock levels.

- **Out of the three depot systems we observed, NADEPs experienced the most backorders affecting production.**

  Although allowances for line items in the supply system appeared to be adequate, the actual stock on hand and the respective estimated delivery dates were detrimental to production. The Navy's backlog approached two to three years, compared to the less than two-year window for the Air Force, and the zero tolerance lead-time for UAS.

- **There were five main common themes that surfaced for the readiness degraders': excessive delivery times in both the Navy and Air Force, unpredictability in forecasting, sole source contracting, a diminishing defense industrial base, and a lack of management of contractors.**

- **Multiple configurations in the Navy's and the Air Force's inventory are very difficult and costly to maintain and directly contribute to unpredictability.**

  Multiple configurations demand multiple aircraft specifications and additional resources in test equipment, training, manpower and inventory.

- **Sole source contracting and a diminishing Defense Industrial Base directly contribute to a poor supply posture.**

  The most severe NADEP lead times involved defaulted sole source contracts, leaving the Navy with no recourse. This lack of recourse is also due to a diminishing defense industrial base. There are several reasons for supplier's lack of participation in government contracts.

  Although the defense acquisition process has moved away from a military specification (MILSPEC) environment to increase flexibility in the commercial contractor base, there are still many federal acquisition controls that deter government business. For example, cost accounting standards require companies to maintain two accounting systems to comply with Generally Accepted Accounting Principals (GAAP) and government standards. The Department of Defense (DoD) is addressing low profits by using best business practices and using more commercial off the shelf acquisitions, but the fact remains that when the economy is doing well, the profit margins are more attractive in the commercial industry.

- **Aging systems contribute to a diminishing Defense Industrial Base.**

  In all depot systems, aging systems caused severe backlogs of required parts. The Navy's S-3 and E-2 aircraft, the Air Force's A-10 and UAS' DC-10 are all examples of aircraft extended beyond their expected life. The Air Force and Navy still maintain these models in their inventory and are experiencing excessive cycle times. UAS remedied their situation by purchasing spare aircraft for parts and eventually replaced the model.

- **All readiness degraders in our study revealed a lack of aggressiveness in contracting and item managers.**

  Several backorder cases involved parts of which item managers were unaware or had limited time to review and take action. In all cases, this lack of attention was attributed to an overwhelming workload, resulting from BRAC, downsizing and ALC/NADEP consolidation. These events increased contract requirements and decreased the manpower to

administer them. The readiness degrader data appeared to support these statements.

In many such cases, there was zero stock on hand, and contracts were just beginning the first article test phase. This indicates that quantities on hand fell well below the reorder point before item managers discovered a lapse in the contract or the lack of suppliers with which to initiate contracts. A few of the back orders involved suppliers waiting for a contract to be issued. The side effects inadequate contract management are extremely crippling for an indefinite period, including loss of suppliers in the defense industrial base, and lack of components and respective operating assets. These are all phenomena the Navy is currently experiencing.

- **The contracting process is causing delays affecting production.**
- **The Air Force's and UAS' emphasis on a responsive logistics pipeline is extremely beneficial.**
- While the Air Force's move from three to two maintenance levels is debatable, there is no question that the associated emphasis on a responsive logistics pipeline is extremely beneficial. With the advent of the Internet and e-commerce in the commercial world, the logistics pipeline responsiveness has become the focal point for improving profitability. These commercial applications have significantly improved in technology and speed, and they have phenomenal implications for improving the Navy's readiness.
- **Commercial industry's drive towards profitability has encouraged streamlining current processes and developing new methods of improving efficiency and effectiveness.**

## C. RECOMMENDATIONS

- **Use SMA $_{IPG1\&2}$ formula as a tool to indicate supply readiness posture.**

  The SMA $_{IPG1\&2}$ formula is a more focused measurement tool that narrows-in on readiness critical parts. This provides a more defined indication of supply health in terms of readiness.

- **Eliminate the remaining ASPA programs and assign tail numbers to NADEP schedule ahead of time.**

  Unpredictability cannot be eliminated, but it can be minimized by minimizing unpredictability in the respective sources. One of these sources is the aircraft scheduling and assignment process. The Air Force and UAS capitalize on a more predictable scheduling process by obtaining a profile of expected aircraft. They use a rigid, no exceptions schedule that assigns specific tail numbers to overhaul dates. This allows depots to pre-stage resources and plan a critical path minimizing cycle time and

allowing the asset to return to the fleet quickly. Although the Navy is using IMC to move closer to such a model, the ASPA program still pertains to many platforms and tail numbers are not pre-assigned. We observed the impact of these differences directly at Hill ALC by comparing the C-130 program for the Navy and Air Force aircraft.

- **Pursue standardization of Weapons Systems where possible and specifically focus future acquisition on multi force standardization.**

  UAS as well as the rest of commercial industry observed the costs of multiple configurations. This led them to standardize aircraft configurations through "family of aircraft." This saves time and money in overhaul processes, test equipment, training and inventory. This provides a consistent environment where resource requirements become standardized, and hence more predictable. Additionally, this frees resources through an exponential learning curve, minimizes cycle time and centralizes inventories of spare parts, tools, test equipment, manpower and facilities. Standardization also provides incentives for suppliers to continue producing spare parts and capture economies of scale.

- **Pursue long-term multi-vendor contracts to provide multiple avenues in case of default and encourage more suppliers to remain in the defense industrial base.**

- **Identify factors deterring companies from remaining in the defense industrial base and develop preventive measures.**

- **Review all post production support plans to ensure robust plans exists for potential aging systems.**

  As a safeguard to a diminishing defense industrial base, it is imperative that post production support plans are robust enough to address aging aircraft problems.

  Although replacing aircraft earlier in their life cycle could minimize this problem, a robust post production support program is still critical. We observed this importance in the UAS B777 and A320, new aircraft still in production. Even though United Airlines routinely replaces their aircraft earlier in their life cycle, a good post production support plan would have eliminated some of the support difficulties they encountered with current models that are not yet aged.

- **Review contract specialist and item manager staffing to determine if workload is balanced or an increase in staff is required.**

  The data we collected did not definitively support a requirement for additional manpower; however, this information is well enough substantiated to study workload and manpower and identify any trends across item managers in excessive workloads and inadequate attention to inventory levels. UAS did not show any signs of delay in contracting

because they take a long-term multi-vendor approach aggressively managing suppliers with heavy monetary penalties.

- **Place supply personnel or material managers under the reporting cognizance of the production "fixers."**

- If fixers write supply evaluations, the measure of performance of supply is directly related to production and subsequently readiness. Often times, when this relationship does not occur, supply personnel create performance objectives related to inventory efficiency or cost savings alone. Although these personal performance concepts of inventory efficiency and cost savings are beneficial to a depot, they mean little if they cause excessive lead times to production that can prove to be even more costly.

- **Continue to discover says to streamline this contracting process to enable rapid response to emerging needs.**

- **Conduct a study on current logistics concepts for application to DoD logistics.**

- **Incorporate a "readiness equals profit" mentality in DoD business planning**

  Although DoD is a government agency that cannot pursue monetary profit, we can experience the same benefits by equating profit to readiness. The improvements the commercial industry seeks to improve profit are the same improvements that will improve readiness. Although readiness is difficult to measure, it is the profit that we must use as a driving concept. Readiness equals profit.

## D. RECOMMENDATIONS FOR FUTURE STUDY

- Complete a workload efficiency review of item manager and contracting specialist positions

- Evaluate the effectiveness of Post Production Support Planning

- Identify and analyze the Defense Industrial Base

- Analyze the costs and benefits of multi-force weapon system standardization

- Study the value added in the Contracting Process

- Analyze the Costs and Benefits of outsourcing contract management functions

- Analyze the Cost Benefits of maintaining aged aircraft systems compared to procuring new aircraft systems

- Identify and analyze readiness measurement tools
- Assess the effectiveness of a two versus three level maintenance system
- Examine the benefits of a rigid depot scheduling system
- Analyze the effects of aging systems on maintenance manhours
- Assess the effects of aging systems on supply requirements

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